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ABSTRACT

Scientific sense-making is a process in which theory and evidence are brought into coordination. This paper reports on research undertaken as part of a larger National Science Foundation funded study on the conditions that support scientific sense-making in schools. It describes how students with access to a range of epistemologies contribute in different ways to a conversation about a toy called a Magic Eight Ball. The investigators assert that conversations of this type may provide critical learning opportunities for students who are developing new ways of thinking about what it means to know something, and what it means to do science. This discussion is intended for use by teachers and science educators who wish to give scientific sense-making a more prominent role in the classroom than it presently enjoys. (ZWH)

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Sense-making Conversations and Student Epistemologies

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Sense-Making Conversations and Student Epistemologies

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Abstract

This paper reports on research undertaken as part of a larger NSF-funded study on the conditions that support scientific "sense-making" in schools.[1] In this paper we show how students with access to a range of epistemologies (ways of knowing about the world) contribute in different ways to a conversation about a toy called a "Magic Eight Ball" We suggest that conversations of this type may provide critical learning opportunities for students who are developing new ways of thinking about what it means to know something, and what it means to do science. We hope that this discussion will be useful to teachers and science educators who wish to give scientific sense-making a more prominent role in the classroom than it presently enjoys.

Theoretical Context: What is Sense-Making?[1]

In the spirit of D. Kuhn (1989), we define scientific sense-making as the endeavor to construct and articulate, in collaboration with others, explanations of observed phenomena by coordinating an emerging theoretical model with available data (see Newman, Morrison, & Torzs, in press).

Several components of this definition deserve special emphasis. First, we distinguish *scientific* sense-making from the more ordinary sense of the term, in which "making sense of something" may mean no more than bringing an observation about the world into accord with one's personal viewpoint. Sense-making, in our use of the term, implies not only an effort of individual cognition, but an attempt to articulate the effort publicly. In other words, the goal is to make sense with and to others as well as to oneself. Sense-making is thus a communal effort, undertaken as a member of a sense-making community.

Second, although we are interested in the collaborative construction of explanations, we do not care about aligning ourselves with any particular constructivist stance. In particular, our use of the term sense-making should not be taken to imply an Aristotelian or empiricist concern with the relationship between sensory impressions and the "objective reality" of natural objects and processes. Our fundamental distinction is not between internally constructed models of the world and the world itself, but between publicly articulated, theoretical constructs (theories, models, explanations of various kinds), and the real-world observations and measurements that these theoretical constructs seek to describe and explain (Mathews, 1993). Observations and measurements—presented in forms such as lists, graphs, and tables of data—prompt and support theory. Theory, often instantiated in the form of models (physical, mathematical, or otherwise), explains and predicts data. These artifacts are available to public scrutiny, making it possible for a sense-making community to discuss the degree to which the two are coordinated, in a way that is independent of "common sense" understanding.

Third, as educational researchers, we are more centrally concerned with the process of sense-making than with its product. Our perspective is therefore different from that of researchers focusing on student misconceptions of phenomena, where the interest is in identifying

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stages of cognitive change in which students adopt increasingly accurate understandings, with the ultimate goal being the accepted "scientific" account. Although we have been looking at science lessons in a particular domain (seasonal change) and have noted a variety of misconceptions, we are primarily interested in how students talk about this domain, and what this talk reveals about their developing understanding of what it means to do science.

Finally, a fundamental notion underlying a great deal of our thinking about sense-making is the notion of sense-making as conversation. This is tied to our definition of sense-making as a public, collaborative enterprise. As explained in Newman, Crowder & Morrison (in press), we define a sense-making conversation as an idealized, culturally-defined way of organizing talk. As in ordinary conversation, participants tacitly agree to cooperate, to maintain relevance (Grice, 1975), and to take turns (Sacks, Schegloff, and Jefferson, 1974). What makes it a *sense-making* conversation is that participants appear to be engaged (more or less consciously) in a collaborative task whose purpose is to construct a mutually acceptable explanation of a situation by coordinating, as separate constructs, theory and data. In support of this goal, participants tacitly agree that all explanations are tentative, inherently open to challenge, and accountable to, and only to, the available evidence.

Possible moves in sense-making conversations include framing a question, denying that a question is important, proposing an explanation, or a partial one, rejecting an explanation by pointing to contradictory data, presenting relevant data, arguing that presented data is irrelevant, suggesting a new method of measurement, arguing that measurements are not sufficiently precise, and so on. Sense-making conversations may be face-to-face, or conducted at a distance; they may be verbal, written, or involve a mixture of media; they may extend over a few minutes, or many years; they may involve just two participants, or thousands.

The capacity to engage in these kinds of conversations (both face to face and in writing) is, we assume, an important ingredient of scientific literacy in our culture—perhaps the key ingredient. However, as Kuhn (1989) has shown, the ability to distinguish between theory and data does not arise naturally as a developmental stage. Adults as well as children often fail to make the distinction, preferring to explain phenomena in terms of "the way things are." Also, as Lemke (1990) and Cazden (1988) have reported, conversations of any kind are relatively infrequent in typical science classrooms, where textbook-based lectures and "triadic" dialogs involving the teacher and individual students tend to be the dominant language activities. As a result, students have few chances to engage in the real business of science.

If students are to develop the way of speaking and knowing that we call "sense-making," they need to spend some part of their day thinking, working and conversing in a community in which at least some people are accustomed to making sense of puzzling phenomena by coordinating theory and evidence in collaboration with others. In such a community, one might expect to find conversations that some participants treat *as if* they were sense-making conversations, while others treat them *as if* they were, say, conversations about "the way things are." By challenging "theories," by asking for evidence, and by refusing to acknowledge a single "correct answer," we hypothesize that the more expert sense-makers in the community provide crucial learning opportunities for those who are less expert, who may, if they wish, begin to adopt new ways of speaking and knowing.

History of Research Program

We have been looking at sense-making and the conditions that might support it in five different classrooms: two attached (team-taught) classrooms in a predominately white, middle-class suburb of Boston; one classroom in an ethnically-diverse alternative school in a community across the river from Boston, and two classrooms in an inner-city school in New York City serving a primarily African-American population. In all five classrooms, the content focus has been a year-long unit on the topic of Earth and Sun. Teachers ask students to think about what makes day and night, why shadows are longer at sunset than at noon, why the days get shorter and then longer during the school year, why

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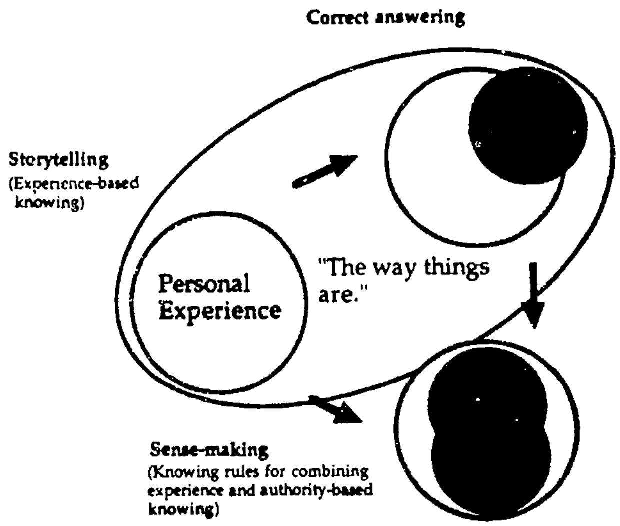
midday shadows are longer in Alaska than in New York on the same day, and so on.

In analyzing videotapes of these lessons, we have found it useful to distinguish three categories of student science talk: *storytelling, correct answers*, and *sense-making*. As explained in Théberge, Crowder, and Morrison (forthcoming) storytelling, in our definition, is an ordinary, unschooled way of talking about natural phenomena using a primarily narrative form—a sort of sharing—reflecting an experienced-based way of knowing about the world. Attempting to give "correct" answers—culled from teachers' lectures or textbooks—is more clearly a "schooled" way of talking science, reflecting an authority-based way of knowing. Both storytelling and correct answering reflect a "way things are" epistemology (Kuhn, 1989).

As explained earlier, we define *sense-making* as science talk that shows, above all, an attempt to coordinate a theory about the world with evidence that supports it. Knowing how to take part in sense-making conversations means knowing the rules or patterns (all culture-specific) for combining, seeking, and interpreting both experience-based and authority-based ways of knowing. It is not necessary that the theory be correct, nor that the evidence be actually substantiating—only that the distinction be at least implicitly recognized. Sense-making talk is organized around the systematic collection of data or the use of subsequent data to revise theory; designing experiments to validate or invalidate models or claims; and using models to generate data.



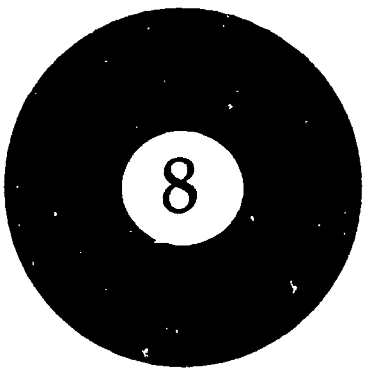
The Magic Eight-Ball Task

After observing, taping, and reviewing many hours of classroom discussion in our 1991-92 data, we felt confident that we had seen significant change in several students' ways of talking about the world—a movement from storytelling and correct answering to sense-making. However, as recounted in Théberge, Crowder, and Morrison (forthcoming) this was not reflected to the extent that we had expected in our year-end interviews. Interview questions about specific phenomena, (e.g. What makes the seasons change?, If it is summer in Boston, is it summer everywhere on the globe?) tended to elicit "correct" answers almost exclusively. Students seemed to take these as typical school questions requiring correct answers even though we knew (from classroom observations) that some of these students were capable of something more like sense-making.

In an attempt to solve this problem, we designed a new set of tasks aimed at eliciting a broader range of science talk. One of these tasks involves engaging students in a discussion about how a popular toy called a "Magic Eight Ball" works.

The toy is a black plastic sphere about five inches in diameter with a round window in its base. To play the game, you ask a "yes or no" question, then turn the ball upside down. An answer to the question (e.g., "Reply hazy. Ask again." or "You can count on it") appears in the window. The actual mechanism—a polyhedron floating in a liquid bath rises to the surface, displaying one of its faces at random—is not directly apparent. However, by recording the number of different responses that come up over repeated trials, then combining this information with different geometric solutions, it is possible to construct a reasonable theory about how the toy works. For example, two octahedrons would give 16 possible responses.

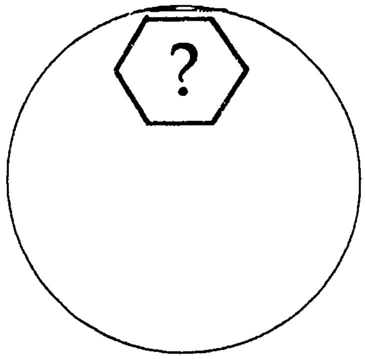
Our preliminary findings suggest that the Eight Ball task does indeed elicit something more like sense-making than the more traditional interview questions we had been using. Of twenty-five fifth- and sixth-grade students we interviewed at the beginning of the school year 1992-1993, more than half took what we coded as a "sense-making" approach to the Eight Ball task. In contrast, a standard question about the cause of seasonal change produced a sense-making approach from only one student (Théberge, Crowder, and Morrison, forthcoming).



1. Top view (external).

2. Top view of base with mechanism inverted.

We have found that the Eight Ball task also serves as an interesting conversation prompt for small groups, allowing us to look at how students with apparently different epistemologies interact.



3. Hypothetical side view (internal).

The remaining sections of this paper focus on a few minutes of one such conversation, among a research assistant and four African-American sixth-grade students at our New York City site. We begin by presenting an overview of the entire segment, then discuss some key points.

The Conversation

The research assistant had previously interviewed each of the students separately using the Eight Ball task. Now she has brought them together for a group discussion. She opens the conversation by asking the group as a whole how the toy works. The students take turns answering, working gradually, though perhaps not intentionally, toward a common understanding of how the toy works.

The first student, Keith, focuses on how the mechanism works in a general sense:

Keith: Well, I think this is full of like [taps window] blue ink... or something like that... and it's paper. And every time you do like this...cause it's up here right now...cause it's like half full of water...it's up here now and you turn it around and it comes up here.

Giselle wants to talk about the number of "triangles" inside:

Giselle: I think it has more, about two triangles.
Research Assistant: I can't hear you

Giselle: I think it has...
Keith: Everybody knows that.
Jenelle: Stop Keith.
Giselle: I think it has two triangles or more.
R.A.: Two triangles in the water.
Giselle: Or more.

As becomes clear later on, by "triangles" Giselle probably means polyhedrons with triangular faces. In other words, she seems to think there are two or more objects floating inside the sphere.

Bobby now gives a general description of how the toy works:

Bobby: I think uhm that when you ask it a question and then turn it over, that it's like a certain kind of liquid that pushes it up to the top.

Jenelle accepts the general mechanism proposed by Keith and Bobby, but disagrees with Keith's assertion that the liquid inside the toy is "blue ink."

Jenelle: Uh, I think that it's, it looks like blue ink in this, but I think really think it's just water. That the eight ball inside is just so dark that it makes the water in the dark and look like ink and the pressure of the water pushes the block [?] up to the top.
Keith: [amused] Pressure?
Jenelle: [laughs, as if embarrassed] I mean, not the pressure, like yeah sort of in a way.

Her description prompts Keith to suggest the metaphor of a float valve in a flush toilet:

Keith: I know what you're saying, it's like a toilet.
Jenelle: Yeah like when you turn it over...
Keith: You take off the top
Jenelle: It's just like a toilet.
Giselle: It's like a toilet.
Jenelle: You flush it and it pops up.
Keith: You take the top off you see that black ball.
RA: Does everybody agree on that?
Keith: Yes, [tapping his own chest] we agree.
Giselle: I agree.
Keith: [with drama] We are civilized people.

Shortly after this exchange, the research assistant tries to get the students talking about the geometry of the floating shape inside. After a false start or two, Bobby asks the research assistant to show the group a paper model he constructed demonstrating his understanding of what the shape might look like.[2]

RA: Keith you were shaking your head when Giselle said something about two triangles.
Keith: I said, yeah, cause it is more than one triangle in there.
Jenelle: You were shaking your head when Bobby said something and you said Nooooo.
Bobby: I already made it. Show them that thing I made.
RA: Oh, okay. [puts paper model that Bobby had made previously on the table.]
Keith: [playing with the toy] I got "Ask again later."
Jenelle: Oh, that's a fortune paper.
RA: Okay. That's what Bobby thinks is inside. What do you guys think?
Giselle: Yup, it is.
Jenelle: I think...yeah...like that. That's what I was trying to explain.

Bobby's paper construction, an octahedron, is apparently at least roughly in accord with Giselle's and Jenelle's sense of the shape inside the ball. As it turns out, the paper model becomes a major object of conversation later on and helps the group focus more directly on the basic geometrical problem the toy poses.

At this point, however, Keith notices the "bubbles," a discovery that will become another major topic—at least for Keith and Jenelle:

Keith: Look at that. Look at those little bubbles in there. It's a chemical in here.
Bobby: Like I said, it's probably liquid.
Jenelle: No it's not. I think it's...
Keith: It's a chemical. Look at these little tiny bubbles. You don't see them little tiny bubbles in water. It's a chemical.
Bobby: 'ats a [?] chemical.
Jenelle: It may be a little bit...It may be a couple. But I really think it's just the darkness inside of it.

Later on we'll see Jenelle use this same tactic again, playfully conceding some small degree of agreement with Keith's "chemical" theory,

[2] As reported in Théberge, Crowder, and Morrison (forthcoming). Bobby had originally drawn a pyramid with a square base. Later, while constructing a paper model to see whether the pyramid would ever land with its square face up, he discovered the possiblity of joining two pyramids together at the base, thus creating an octahedron.

while in fact maintaining a strong position against it.

Giselle now introduces yet another topic—whether the toy's answers can be trusted:

Giselle: Jenelle, when you ask the thing a question, it don't know the answer to the question.
Keith: It's just whatever [?] comes up. Like, "Ask again later," right?
Jenelle: It just puts it. It'll just come up. If you say, I want to be this, it'll come up and say you're very doubtful.
Giselle: And then when you turn it over and you put it down and you turn it back up
Bobby: You got to ask it a yes or no question.
Jenelle: It's like a fake fortune.
RA: You don't think it's real?
Keith: [Reading in the window.] "It is decidedly so."
RA: What do you guys think?
Jenelle: I think. Wait a minute. Tell you honest? I think that it *could* be real, but I don't think that it's really telling your fortune. It could be real. I could say "I want to be a lawyer" and it could say, that's very good. It could really be a good idea. But I don't really think, [to the boys] shut up. But I don't really think it's a real fortune. It's a fake fortune.
RA: Giselle?
Giselle: [Holding the paper model] It has it has it has more than two things here and each side has a different opinion. And it turns around...
Keith: [Reading] "Very doubtful."
Giselle: And it turns around...the water makes it turn around.

By this point, the group seems to have developed a basic, common understanding of how the toy works—one or more objects ("triangles") floating in a liquid with different words ("opinions") rise to the top, like a float valve in a flush toilet. The liquid may be a "chemical," or it may be just water, made dark by enclosure inside the sphere. And it seems generally agreed that the answers are "fake"—at least no one seems willing to argue to the contrary.

Using Billy's model as a prompt, the research assistant again tries to focus the group on nature of the object (or objects) inside and the number of sides:

RA: So does everybody think it's that shape [the shape of Billy's model] that's inside here?
Giselle: Yes.
Jenelle: In a way, yeah. In a way.
RA: How many sides does that thing have?
Keith: [Holding Bobby's paper model and counting] One, two three, four, five, six, seven, eight.
RA: OK, so there would only be eight answers in there, right?
Bobby: How many answers?
Keith: Well, there's two answers...
Jenelle: Well you never know. Let's say you shake it up
Keith: [Inspecting the toy] That has four sides
Jenelle: ...and you could maybe count the answers. But I don't know how many answers it has.
Keith: That has four sides.
Bobby: I went and discovered a new way [?]...instead of cutting on top ...look I went and cut a triangle instead of a square and putting a square in the middle.
Keith: Let's see the shape.
Bobby: ...put a square right here in the middle and glued it together. What I had did was cut out a triangle to find five sides instead of eight and then I put triangles on the side of the triangles.

As reported in Théberge, Crowder, and Morrison (forthcoming), during the interview session prior to this group discussion, Bobby had drawn a picture of what he thought the shape might look like—an object with a square base and four triangular sides. When the interviewer asked him if he had ever seen anything other than triangles in the window, Bobby suggested making a paper model, then rolling it like a die to see whether it would ever display a square. Apparently while making this model, he had the idea of making two, then gluing them together at the base, thus creating the octahedron.

In another context, Bobby's description of his method of constructing his model might be seen as a merely a kind of storytelling. In the context of *this* conversation, even though his contribution has the surface form of a story, it functions as a report on an experiment, the results of which are relevant to the issue at hand—the shape of the object inside the toy.

Keith now suggests a practical means of getting the "correct" answer, Keith: Can't you just look on the side of the box and see what it is?

Jenelle: No, because this is supposed to be what we *think* it is.

then immediately returns to his "chemicals" question:

Keith: [Back to looking at the window]."Excellent." It's a chemical. It's a kind of a chemical.

RA: What are you looking at Keith?

Keith: Look at these little bubbles.

Jenelle: No it's not a chemical.

RA: Well, what makes you think it's a chemical and what makes you think it's not a chemical?

Keith: Cause, these little tiny bubbles in here.

Jenelle: So? In water...

Keith: No, they were little like this, and plus, they put chemicals in a lot of things.

Giselle: But you don't know it has chemicals in it.

Keith: But I'm saying...

Jenelle: It probably is maybe a *touch* of chemical [making big eyes].

Keith: Here we go again.

This is the point in the conversation where basic epistemological issues become most explicit. Keith's assertion that the liquid inside the ball is a "chemical" is based on a kind of fallacious deductive reasoning—the liquid has tiny bubbles, chemicals have tiny bubbles, therefore the liquid is a chemical. Besides, "they" put chemicals in a lot of things, so there's a high probability that this particular thing has chemicals in it. Jenelle's playful concession ("It probably is maybe a *touch* of chemical"), might be taken to suggest that *she*, for one, is not really convinced by this kind of logic. Giselle's objection is much more direct; in her opinion, Keith doesn't *know* that the toy has chemicals in it. Another way of saying this is that her way of knowing is not the same as Keith. In a sense, the two are operating with different epistemologies.

Shortly after this, the researcher again tries to bring the conversation back to the geometry issues. It is interesting that much of the talk is now about *not* knowing.

RA: Let's come back to the ball. Now you told me the model that Bobby made has eight sides.

Giselle: Yes.

Jenelle: I don't...I don't know.

Keith: Maybe.

Jenelle: Maybe because the eight ball. Maybe.

Keith: Maybe. It's probably four. It might be four.

Bobby: It's five sides.

Jenelle: Maybe because it has eight. It says it's number eight.

RA: Why do you say there were five?

Keith: [Looking in the window and counting] One, two, three, four.

Bobby: Because when I cut out

Keith: There's four. One, two, three, four...

RA: Come on, let's listen to Bobby. Bobby, why do you think it's five?

Bobby: Because when you cut up a triangle, right, and that's like flat right here? I cut another triangle on that side. And one on that side. And one on that side. Oh yeah, that's four.

Jenelle: That's four. I told you.

Keith: I'm a mathematician.

RA: Okay, but then, well, how many answers do we have then total?

Jenelle: It's like an answer on each side. What I think, it's like there's an answer on each side.

Keith: I think there's like eight answers in there.

Jenelle: Me too, because it says the number eight.

Keith: 'cause there's like two triangles...

In answer to the researcher's question, Giselle confirms that Bobby's paper model has eight sides. Jenelle says she doesn't know. Because the paper model clearly does have eight sides— Keith has already counted them— we take this to mean that she doesn't know how many sides the shape inside the toy has. Maybe, (but only maybe) it has eight, because, after all, it's an "eight ball." Keith concedes that while this *may* be true, there are in fact "probably" four sides, or at least there "might" be four. Bobby states, with some certainty, that there are five sides, by which he may have meant the five sides on his original pyramid, which had a square base and four triangular sides.

Giselle now introduces an important new piece of information:

Giselle: It's more than eight.

Keith: [looking in the window and counting] One, two...

Giselle: Remember when we wrote all the answers on the paper

Bobby: It's eight.

Giselle: And there were more than twelve?

RA: Okay, now listen to Giselle. Listen to her.

Giselle: Me and uhm [can't remember RA's name] Miss we had wrote on a paper all the answers that we saw and it was more, it was more than twelve.
Keith: It was like twelve?
Giselle: It was more than twelve.
Keith: It was about like fourteen? I mean uhm
Giselle: It might be, it might be...
Keith: Sixteen. About like sixteen?
Giselle: Yeah, about sixteen.
Keith: So there should be...
Giselle: Two triangles
Keith: ...four triangles in here. Four times four is sixteen. Four triangles in there.

During her previous interview, Giselle and the research assistant had done some systematic data collection—repeatedly tipping the toy over, reading answers, and making a list. The results, which Giselle cannot recall exactly, have an immediate impact on the course of the discussion. Since there were more than eight, this rules out a single octahedron. Keith suggests that there might have been sixteen possible answers, which is consistent with his notion of a four-sided "triangle" (polyhedron). It is also consistent with Giselle's theory, expressed at the very beginning of the conversation, of two "triangles," assuming each has eight sides.

Although this is neat, it's not enough for Bobby:

Bobby: How could there be a way that there would be six triangles in one?
Jenelle: [after three-second pause] It's sides, Bobby, it's sides!
Bobby: I'm just saying it could be a way?
Jenelle: It's sides of that triangle.
Bobby: And it could be three triangles.
Jenelle: Stupid...
Keith: [laughing heartily] It's funny but I think there is four triangles in there.
Jenelle: Me too. Because maybe when the first side goes down, the other side comes up.
Keith: I got an idea. Let's go get a sledgehammer. [making shushing noise] and all the stuff come out.
Giselle: [Making a dismissive gesture with her hand] That's violent.
Keith: You could analyze it. You could take a test tube and you'd be like [pretends to be gazing into a test tube].
Bobby: Scientist [gesturing as if holding some kind of apparatus and making a hissing sound].

Although it's difficult to know exactly what Bobby's issue is (Did he hear "six" when Giselle said "sixteen?"), it is significant that, for Bobby, it appears not to be sufficient that a theory about the shape of hidden object or objects happens to be consistent with Giselle's vague recollection of the number of answers. For him, it must also be geometrically possible, i.e., consistent with a model such as the one he has attempted to construct.

This is not, by any means, the end of the conversation. The topics raised in the segment reported here—the veracity of the fortune, the "chemicals" question, and the nature of the object inside, all get revisited. There is a long stretch in which the four students have a merry time asking the toy whether they'll have boyfriends or girlfriends in the future. Later, all four collaborate on replicating Giselle's experiment, collecting as many different answers as they can find and writing them down. This is followed by another heated discussion about how many different "triangles" there are, and how many sides they have.

Discussion

It is useful to consider what sort of conversation this is not. The participants might have taken a more classically "scientific" approach—first agreeing on an interesting question, then constructing a testable hypothesis and collecting data to confirm or refute it (not that practicing scientists actually do this very often). Or they might have simply exchanged "opinions," or stories, or spent the time asking the toy questions. Or one participant might have given the "correct answer" (three octahedrons?), thus making all further conversation unnecessary.

None of these things happen. Rather, off and on, at different times, and with varying levels of interest, the participants deal with at least four questions, none of which is ever fully answered: the nature of the liquid inside the toy (water? ink? chemicals?); how the mechanism works in a physical sense (the question of buoyancy); how many sides the "triangle" inside has; and whether or not the fortune is "fake." In the process, plenty of different "opinions" are expressed, there is at least one wistful appeal to authority-based knowledge ("Can't you just look on the side of the box and see what it is?");

there is also a considerable amount of joking, verbal jousting ("It probably is maybe a *touch* of chemical"), and just plain fooling around.

What we have here, in other words, is a kind of hybrid discourse. This is not strictly a sense-making conversation in the ideal form in which we have defined it. Nor is it simply a quest for the correct answer. Importantly, as may be the case in "real" scientific discussions, there are elements of sense-making, story-telling, and correct answering all mixed together.

Three points in the conversation are particularly worth revisiting. The first comes when Bobby introduces his paper model:

Bobby: I already made it. Show them that thing I made.
RA: Oh, okay. [puts paper model that Bobby had made previously on the table.]
Keith: [playing with the toy] I got "Ask again later."
Jenelle: Oh, that's a fortune paper.
RA: Okay. That's what Bobby thinks is inside. What do you guys think?
Giselle: Yup, it is.
Jenelle: I think...yeah...like that. That's what I was trying to explain.

Presumably, each participant has some sort of private mental model of what the hidden object inside the toy looks like. Bobby's important contribution is to produce a public model—which, because it is public and exactly specified (mathematized), stands as both a formal hypothesis, and a framework for generating additional hypotheses.

A second critical juncture occurs when Giselle introduces the fact that she has already done some relevant research:

Giselle: Me and uhm [can't remember RA's name] Miss we had wrote on a paper all the answers that we saw and it was more, it was more than twelve.
Keith: It was like twelve?
Giselle: It was more than twelve.

The significance of Giselle's contribution is that it introduces the possibility of evidence, and a way of collecting it. Combined with Bobby's paper model, the groundwork is laid for the coordination of theory and data.

For our purposes, it doesn't really matter that this groundwork is not immediately put to use. The important point is that Bobby's theory about the shape inside the eight ball is articulated as a formal, public model. Giselle's theory is based on the collection of evidence. Both suggest a way of knowing that is very different from Keith's direct observations and axiomatic reasoning about the "chemicals," or Jenelle's suggestion of a possible correspondence between the name of the toy and the number of answers (sides) it has. In other words, what we see demonstrated here is an example of a situation in which students with a range of different ways of talking and knowing come together to converse, thereby creating at least an opportunity for cognitive change. Clearly, the research assistant plays an important role in the conversation, especially in terms of steering it towards the basic geometry question. Although it may be interesting to consider how the conversation might have developed without such support, the researcher's interventions do not, for us, invalidate the basic finding. Given the opportunity, students at this age can engage in meaningful sense-making conversations. Classroom science lessons need to provide more opportunities of this type.

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